DOCUMENT RESUME

ED 395 826 SE 058 540

AUTHOR Vogt, Gregory L.; Rosenberg, Carla B.
TITLE Solar System Puzzle Kit: An Activity for Earth and Space Science.
INSTITUTION National Aeronautics and Space Administration, Washington, DC. Education Dept.
REPORT NO EP-328-6/95
PUB DATE Jun 95
NOTE 27p.
AVAILABLE FROM NASA, Education Division, Mail Code FET, Washington, DC 20546-0001; Electronic version: Telnet: spacelink.msfc.nasa.gov; http://spacelink.msfc.nasa.gov
PUB TYPE Guides - Classroom Use - Teaching Guides (For Teacher) (052)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Elementary Education; *Puzzles; Science Activities; *Solar System; *Space Sciences

ABSTRACT

This Solar System Puzzle Kit for grades 5-8, allows students to create an eight-cube paper puzzle of the solar system and may be duplicated for classroom use or used as a take home activity for children and parents. By assembling the puzzle, hand-coloring the bodies of the solar system, and viewing the puzzle's 12 sides, students can reinforce their knowledge of the many fascinating worlds that make up the solar system. In addition to puzzle pieces, the kit contains interesting facts about the Sun, each of the planets, asteroids, and comets. The resource section at the end of the publication provides sources to obtain additional resources on the solar system including those on the Internet.

**********
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
**********

ED 395 826

National Aeronautics and Space Administration

Office of Human Resources and Education
Education Division

| Educational Product | |
|---|---|
| Teachers & Students | Grades 5-8 |

# Solar System Puzzle Kit:

## An Activity for Earth and Space Science

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
This document has been reproduced as received from the person or organization originating it.
Minor changes have been made to improve reproduction quality.
Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

SE 058 540

BEST COPY AVAILABLE

SpaceLink

*The Solar System Puzzle Kit: An Activity for Earth and Space Science* is available in electronic format through NASA Spacelink—NASA's electronic information system for education.

The system may be accessed by computer through direct-dial modem or the Internet.

| | |
|---|---|
| Modem line: | (205) 895-0028 |
| Terminal emulation: | VT-100 required |
| Data format: | 8-N-1 |
| Telnet: | spacelink.msfc.nasa.gov |

Spacelink fully supports the following Internet services:

| | |
|---|---|
| World Wide Web: | http://spacelink.msfc.nasa.gov |
| Gopher: | spacelink.msfc.nasa.gov |
| Anonymous FTP: | spacelink.msfc.nasa.gov |
| Internet TCP/ IP address: | 192.149.89.61 |

# Acknowledgements

The Solar System Puzzle Kit was designed for the National Aeronautics and Space Administration by the:

Office of Human Resources and Education
Education Division

and the

Office of Space Science
Solar System Exploration Division.

Designer:
**Gregory L. Vogt, Ed.D.**
Teaching From Space Program
NASA Johnson Space Center
Houston, TX

Writers:
**Gregory L. Vogt, Ed.D.**
Teaching From Space Program
NASA Johnson Space Center
Houston, TX

**Carla B. Rosenberg**
Teaching From Space Program
NASA Headquarters
Washington, DC

Contributors:
**Jens T. Feeley**
Office of Space Science
Solar System Exploration Division
NASA Headquarters
Washington, DC

**Joseph M. Boyce**
Office of Space Science
Solar System Exploration Division
NASA Headquarters
Washington, DC

Editor:
**Carla B. Rosenberg**
Teaching From Space Program
NASA Headquarters
Washington, DC

This publication is in the Public Domain and is not protected by copyright.
Permission for duplication is not required.

# Table of Contents

Acknowledgements ..... i
Introduction ..... 1
Sun ..... 2
Mercury ..... 2
Venus ..... 3
Earth ..... 3
Mars ..... 4
Jupiter ..... 4
Saturn ..... 5
Uranus ..... 5
Neptune ..... 6
Pluto ..... 6
Asteroids ..... 7
Comets ..... 7
Solar System Statistics ..... 8
Instructions for Puzzle Assembly ..... 9
Color Guide ..... 10
Puzzle Pieces ..... 11
NASA Resources for Educators ..... 27
Electronic Resources for Educators ..... 28
Evaluation Mailer ..... Back Cover

1

# Introduction

The Solar System Puzzle Kit allows students to create an eight-cube paper puzzle of the solar system with the enclosed kit. The kit may be duplicated for classroom use. It is also recommended as a take home activity for children and parents.

By assembling the puzzle, hand-coloring the bodies of the solar system, and viewing the puzzle's 12 sides, students will reinforce their knowledge of the many fascinating worlds that make up our solar system.

In addition to puzzle pieces, the kit contains interesting facts about the Sun, each of the planets, asteroids, and comets. The resource section at the end of the publication provides sources to obtain additional resources on the solar system including those on the Internet.

# NASA Images

Some of the vast collection of images from the National Aeronautics and Space Administration (NASA) have been converted into sketches for this solar system puzzle kit. These images come from a variety of sources, collected over more than 30 years from spacecraft that have travelled—and in some cases are still traveling—throughout the solar system to learn more about the Sun and planets.

Through flyby spacecraft, orbiters, atmospheric probes, and landers, NASA has studied all of the planets from close range except Pluto. However, Pluto has been observed with the Hubble Space Telescope. A number of satellites have collected images of the Sun, and so have astronauts on board the Skylab space station. Astronauts have taken a total of more than 200,000 photographs of Earth from orbit.

The Soft X-ray Telescope took this space image of the Sun on the Japan/US/UK Yohkoh Mission in 1992.

# Sun

The Sun, the star at the center of our solar system, is about 5 billion years old. The closest star to Earth, it is 145 million km distant (one Astronomical Unit, or AU). The next closest star is 300,000 times further away. Our Sun supports life on Earth and affects the seasons, climate, weather, currents in the ocean, and circulation of the air in the atmosphere.

The Sun is some 333,400 times more massive than Earth (mass = $1.99 \times 10^{30}$ kg), and contains 99.86 percent of the mass of the entire solar system. The ionized gas in the Sun is held together by gravitational attraction, which produces immense internal pressure and high temperatures (more than a billion times greater than Earth's atmosphere).

Inside the Sun's core, temperatures reach 16 million degrees K, which is sufficient to sustain thermonuclear fusion reactions. The total energy generated is 383 billion trillion kilowatts/second (equivalent to 100 billion tons of TNT exploding each second). Radiative and convective zones extend from the core to the surface where the temperature decreases from 8 million to 7,000 degrees K, and the density decreases from 20 g/cm$^3$ to $4 \times 10^{-7}$ g/m$^3$. A photon takes about 10 million years to escape from the dense core to reach the surface of the Sun.

The Sun's surface, or photosphere, is the visible, 500 kilometer-thick layer of escaping radiation, light, and Sun spots. Beyond the photosphere is the chromosphere, which appears during total solar eclipses as a reddish rim of hot hydrogen atoms. The corona extends outward forming the solar wind that sweeps charged particles to the edge of the solar system.

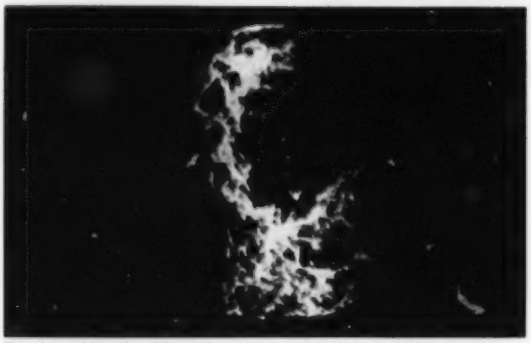
This false-color photomosaic of Mercury is composed of images taken by *Mariner 10* in 1974.

# Mercury

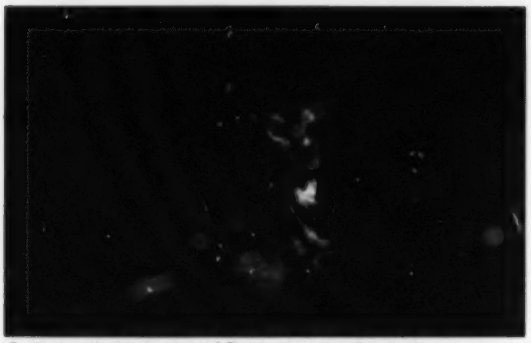
The planet Mercury is the closest to the Sun, orbiting within 46 million km to the Sun at its closest point. Because Mercury rotates on its axis once every 58.9 days and circles the Sun once every 87.9 days, Mercury rotates exactly three times around its axis for every two orbits around the Sun. If you wanted to stay up for one solar day on Mercury (sunrise to sunrise), you would be awake for two Mercurian years (176 Earth days). The surface temperature has the greatest temperature range of any planet or satellite in our system, reaching 427° C on the day side, and -183° C on the night side.

Smaller than all the other planets, except for Pluto, Mercury is about one-third the size of Earth. This planet has a magnetic field, although, Earth's magnetic field is considerably stronger. However, the planet's density (5.4 g/cm$^3$) is about the same as Earth's. Scientists think the density indicates an enormous iron core composing some 75 percent of Mercury's diameter. A rocky mantle and crust only about 600 km thick surrounds the core. When the core and mantle cooled, the radius of the planet reduced by two to four kilometers. The probable result of the planet's crust shrinking is Mercury's unique system of compressive fractures.

Only half of the surface of Mercury has been seen by spacecraft. The heavily cratered upland regions and large areas of smooth plains that surround impact basins resemble the surface of the Moon. Fine-grained soil covers Mercury's surface. Unlike the Moon, regions of gently rolling, smooth plains are the planet's major type of terrain. Eruptions of lava within and surrounding large impact craters formed these smooth plains.



Produced by the *Magellan* mission in 1990, this false-color image of Venus maps the surface of Venus below the clouds.



*Galileo* took this image of Earth showing South America and Antarctica in 1990 at a distance of 2 million km.

## Venus

Venus, the second planet in the solar system, is known throughout history as both the evening and the morning star. Venus is Earth's closest planetary neighbor and is similar to Earth in size, mass, composition, and distance from the Sun. Its scorching surface temperature of about 484° C could melt lead. The planet's atmosphere consists mainly of carbon dioxide with persistent sulfuric acid clouds. This atmosphere is extremely dense, exerting 90 times more pressure than Earth's atmosphere does.

Venus rotates in a direction opposite of Earth, which means that if you were standing on Venus, you would see the Sun rising in the west and setting in the east. The planet rotates sluggishly. In fact, a "day" on Venus (243 Earth days) lasts longer than a Venus year, which lasts 225 Earth days.

The *Magellan* spacecraft mapped 98 percent of the planet revealing a surface consisting of 27 percent lowlands, 65 percent rolling plains, and 8 percent highlands. At least 85 percent of Venus is covered by volcanic rock—mostly lava flows that form the planet's vast plains. Mountains deformed by repeated geologic activity cover much of the remaining surface areas, some stretching 11 km high over the plains. The density of craters formed by the impact of asteroids and comets, at about two craters per million square km, is lower than densities of craters on the Moon or Mars. In fact few craters are smaller than about 25 km in diameter because of the shielding effect of Venus' dense atmosphere. The atmospheric pressure completely crushes and destroys any small meteorites with diameters of less than 1.5 km that pass through the atmosphere.

## Earth

Earth is the third planet from the Sun, the fifth largest planet in the solar system, and the only planet known to harbor life. Earth's diameter is just a few hundred kilometers larger than that of Venus. We experience the planet's rotation as the daily routine of sunrise and sunset, while the four seasons result from Earth's axis of rotation being tilted more than 23 degrees. Our planet's rapid spin and molten nickel-iron core give rise to a magnetic field, which the solar wind distorts into a teardrop shape.

An ocean of air that consists of 78 percent nitrogen, 21 percent oxygen, and 1 percent other constituents envelopes the surface of the planet. This atmosphere shields us from nearly all harmful radiation coming from the Sun, and protects us from meteors as well—most of which burn up before they can strike the surface.

The North American continent continues to move west over the Pacific Ocean basin, roughly at a rate equal to the growth of our fingernails. We are made aware of this movement when it is interrupted by earthquakes. Scientists noticed a distinctive pattern to those earthquakes, leading them to conclude that Earth is dynamic, with its surface separated into moving caps or plates. Earthquakes result when plates grind past one another, ride up over one another, collide to make mountains, or split and separate. These movements are known as plate tectonics.

Oceans at least 4 km deep covers nearly 70 percent of Earth's surface. Water exists in the liquid phase only within a narrow temperature span (0 to 100 °C). This temperature span is especially narrow when contrasted with the full range of temperatures found within the solar system. Water vapor in the atmosphere is responsible for much of Earth's weather.

*Viking Orbiter 1* took images of Mars in 1980 that were used to compose this false-color mosaic.

# Mars

Mars—the fourth planet, the Red Planet—has polar ice caps, and markings that looked, through 19th century telescopes, to be similar to human-made water canals on Earth. American and Russian orbiters did not disclose any canals on Mars, but they did find evidence of surface erosion and dried riverbeds, indicating the planet was once capable of sustaining liquid water. For millions of years, the Martian surface has been barren of water; Mars is too cool and its atmosphere is too thin to allow liquid water to exist. There is no evidence of civilizations, and it is unlikely that there are any extant life forms, but there may be fossils of life-forms from a time when the climate was warmer and liquid water existed.

Mars is a small rocky planet. The surface of Mars retains a record of its evolution, including: volcanism, impact events, and atmospheric effects. Layered terrains near the Martian poles suggest that the planet's climate changes have been periodic, perhaps caused by a regular change in the planet's orbit. The crust of the planet seems to move vertically, with hot lava pushing upwards through the crust to the surface. Periodically great dust storms occur that engulf the entire planet. The effects of these storms are dramatic, including dunes, wind streaks, and wind carved features.

Mars has some remarkable geological characteristics including: the largest volcanic mountain, Olympus Mons (27 km high and 600 km across) in the solar system; volcanoes in the northern Tharsis region that are so huge they deformed the planet's spherical shape; and a gigantic equatorial rift valley, the Vallis Marineris. This canyon system could easily fit the Grand Canyon inside it and stretches the distance equivalent from New York to Los Angeles.

The U.S. Geological Survey produced this color enhanced image of Jupiter from a *Voyager 1* image captured in 1979.

# Jupiter

Jupiter, the fifth planet, is the largest planet, and contains two-thirds of the planetary mass of our solar system. Jupiter is like a small sun with its own miniature solar system; it is composed of hydrogen and helium and has 16 moons, as well as a thin, three-band ring system. Jupiter does not burn like the sun because it contains only one-eightieth of the mass needed to ignite its liquefied gas.

Jupiter's atmosphere contains turbulent cloud layers of ammonia ice, ammonium-hydrogen sulfide crystals, and water ice or perhaps liquid water. The pressure of Jupiter's atmosphere is strong enough to form a layer of liquid metallic hydrogen capable of conducting huge electrical currents. The persistent radio noise and strong magnetic field of Jupiter could emanate from this layer of metallic liquid. Jupiter's magnetic field is immense, pouring billions of watts into Earth's own magnetic field every day. The atmosphere bristles with lightning and swirls with huge storm systems like the Great Red Spot, which have persisted for at least 100 years (and perhaps as long as 300 years).

Comet Shoemaker-Levy 9 struck Jupiter in July, 1994. Discovered in 1993, further observations of the comet revealed that it was in orbit around Jupiter, and had closely passed the giant planet in July, 1992. Jupiter's gravity broke the fragile comet into many chunks of dust and ice during this close approach. For the first time in history, scientists were able to predict that the comet would strike Jupiter and then watch the impact take place. The comet impact itself was a rare occurrence because comets of this size only strike Jupiter once in a millennium.

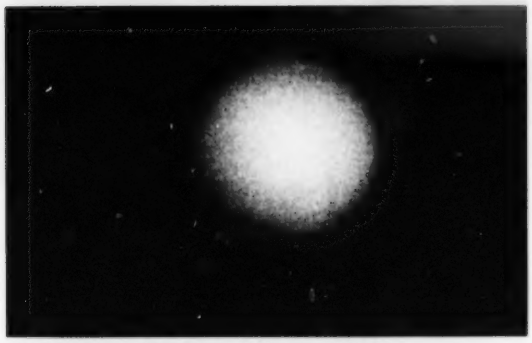
*Voyager 2* took images of Saturn in 1981 from which this true-color image of the planet was assembled.

# Saturn

Saturn, the sixth planet, is a giant, gaseous planet with an intriguing atmosphere. Alternate jet streams of east-west and west-east circulation can be traced in the motions of the cloud tops; the speeds of these jet streams reach as much as 625 km/hr, and are responsible for the banded appearance of the clouds. The atmosphere consists mostly of hydrogen and helium, but also includes trace amounts of other elements. Electrical processes and heat from internal planetary sources enrich the layered chemical mix of the atmosphere, which probably transitions from superheated water near the core to the ammonia ice clouds that are observed at the cloudtop. The planet's atmosphere also features storm structures similar to Jupiter's Great Red Spot. Saturn's magnetic field is 1,000 times stronger than Earth's.

While Jupiter, Uranus, and Neptune also have ring systems, Saturn's ring system is the most extensive and brilliant. Today we know Saturn has 7 major ring divisions. The rings may be the remnants of moons destroyed by tidal interaction with Saturn's gravity. They may include remnants of comets that passed too close to Saturn and were likewise destroyed. Rings are composed mostly of ice crystals ranging in size from a few centimeters to a few meters. The major rings contain hundreds of ringlets, with some rings being "braided," others being flanked with small moons, and shadowy "spokes" developing and dissipating in the rings.

Of Saturn's 18 moons, some are covered in very smooth ice. Saturn's largest moon, Titan, is a little bigger than Mercury and has a thick atmosphere of nitrogen. This nitrogen atmosphere may be similar to primordial Earth, perhaps containing the chemical building blocks of life.



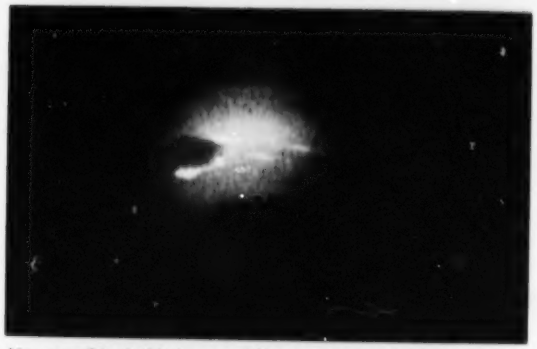
*Voyager 2* took this image of Uranus in 1986.

# Uranus

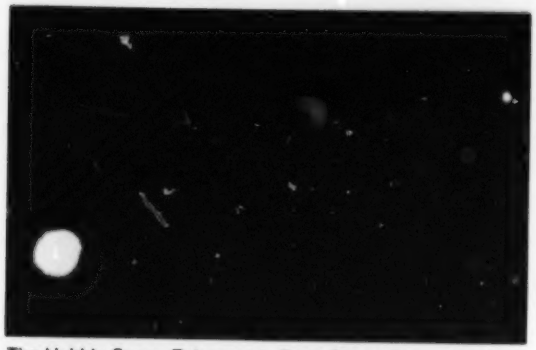
First thought to be a comet, Uranus is the eighth planet from the Sun. Four times the size of Earth, Uranus' orbit extends 19 times farther from the Sun than Earth's orbit. Tipped, Uranus behaves as a giant top as it spins on an axis almost in the plane of orbit. This motion leads to extreme seasonal variation in what sunlight is available. Over the period of 1 Uranian year (84 Earth years), the polar regions of the planet go through four seasons, as on Earth, with perpetual sunlight in the summer, and total darkness in the winter. Periods of alternating day and night are interspersed in the spring and fall. Due to its great distance from the Sun, Uranus temperatures remain a somewhat constant -220° C throughout the year.

Uranus' atmosphere consists primarily of hydrogen and helium with a small amount of methane and other trace amounts of other gases present. The planet's bluish-green color is a result of the methane in the atmosphere absorbing red light. The planet's atmosphere is almost featureless with faint cloud markings between 20° and 50° south latitude. Wind speeds range from 100-600 km/hr and blow westward. At the equator winds were clocked at 1,042 km/hr, over four times faster than the strongest winds on Earth. Uranus has a magnetic field similar in strength to Earth's, but the magnetic field is tipped by about 50 degrees with respect to the axis of rotation.

Uranus possesses a system of at least 11 thin, widely separated rings. The rings of Uranus are optically dark, on the average reflecting only 2 percent of the sunlight that falls on them. Its 15 moons all lie along the planet's equatorial plane, tipped 98 degrees relative to the planets orbit to the Sun.



*Voyager 2* took this image of Neptune in 1989. The image was processed to enhance the features of the planet.



The Hubble Space Telescope's Faint Object Camera took this image of Pluto and Charon in 1994.

# Neptune

Neptune is the seventh planet, and the smallest of the giant gas planets. Its magnetic field—like that of Uranus—is a highly tilted 47 degrees from the axis of rotation.

Neptune receives only three percent as much sunlight as Jupiter, yet it is a dynamic planet and surprisingly shows several large, dark spots. The largest spot, dubbed the Great Dark Spot, was about the size of Earth and was similar to Jupiter's Great Red Spot, which is a hurricane-like storm. Hubble Space Telescope images reveal that the Great Dark Spot is gone. Neptune has the strongest winds on any planet with winds blowing up to 2,000 km/hr. Most of its winds blow westward, opposite to the rotation of the planet. A small irregularly shaped, eastward-moving cloud "scoots" around Neptune every 16 hours or so; this "scooter" could be a cloud plume rising above a deeper cloud deck.

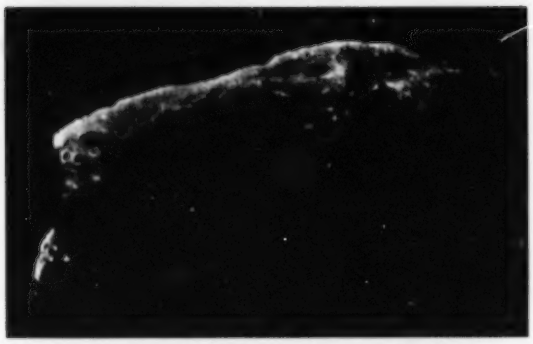
Neptune has four rings and eight moons. The rings appear to be "ring arcs," or partial rings; however, they actually are complete. The rings vary in thickness so that they cannot be fully viewed from Earth. All eight moons are small and remain close to Neptune's equatorial plane. Triton, the largest satellite of Neptune, is one of the most interesting satellites in the solar system. It shows evidence of a remarkable geologic history, with active geyser-like eruptions spewing invisible nitrogen gas and dark dust particles several kilometers into the tenuous atmosphere. Triton's relatively high density and retrograde orbit offer strong evidence that it is not an original member of Neptune's family, but is a captured object.

# Pluto

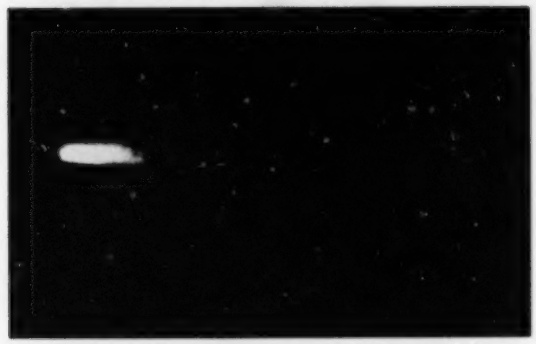
Pluto is the smallest, coldest, and farthest planet from the Sun, with an orbit that is the most elliptical and tilted. Due to its great distance, Pluto has not been visited by spacecraft. As a result we do not know a great deal about Pluto.

We do know that Pluto is very small—smaller than Earth's moon, some 2,330 km across. The planet's surface is slightly reddish, composed of exotic snows of methane, nitrogen, and carbon monoxide. Pluto has polar caps as well as large, dark spots near the equator. Evidence indicates the existence of a rock and water ice interior. Above the surface lies an atmosphere one millionth the density of Earth's. Although the atmosphere is much more tenuous than Earth's, Pluto's low gravity (about 6 percent of Earth's) causes the atmosphere to be much more extended in altitude than Earth's. Because Pluto's orbit is so elliptical, Pluto grows much colder during the part of each orbit when it is far from the Sun. As a result, Pluto's atmosphere is thought to persist only for the part of its orbit when Pluto is closer to the Sun, as it is now.

The moon Charon, which is almost half the size of Pluto, orbits the planet every 6.4 days, at an altitude of about 18,300 km. Given the rough similarity of Pluto's size to Charon's, most planetary scientists refer to Pluto-Charon as a double, or binary, planet. Charon's surface differs from Pluto's; it is covered with dirty water ice and does not reflect as much light as Pluto's surface. Charon's surface is devoid of strong color. To date, scientists have not found evidence to indicate that Charon has an atmosphere.



This mosaic of asteroid 243 Ida was acquired by *Galileo* in 1993 at ranges of 3,057 to 3,821 km.



Taken at Mauna Kea Observatory on Ilia-Jemulson in 1986, this image of Comet Halley stretches over 6° of the sky.

## Asteroids

A large number of rocky and metallic objects orbit around the Sun but are too small to be considered full-fledged planets. These objects are known as asteroids or minor planets. Asteroids are material left over from the formation of the solar system. Some 4,000 numbered and named asteroids circle the Sun between the orbits of Mars and Jupiter. Scientists speculate that an additional 100,000 asteroids exist with diameters greater than 1 km.

The asteroid belt appears to be divided into two very different regions. The inner asteroid belt (inside about 400 million km) is dominated by materials produced by strong heating and melting of the original proto-asteroids, and later fragmentation which has exposed their deep interiors. Beyond 400 million km the belt is dominated by dark objects rich in carbon, organic molecules, and sometimes water-rich clay minerals. These materials could not have survived significant heating, and asteroids in this region probably preserve much information about the formation of the solar system.

A few asteroids in the inner portion of the asteroid belt are referred to as Mars-crossing or Amor asteroids, because the orbits of these objects cross that of Mars. In addition, well over 30 objects have been located that come in far enough to cross Earth's orbit. These Earth-crossing, or Apollo asteroids, usually measure a few kilometers in diameter, or less, with the largest measuring about 8 km across. Most Earth-crossing asteroids appear to originate in the main asteroid belt. There is evidence that Earth has been hit by asteroids in the past. One of the least eroded, best preserved examples is the Barringer Meteor Crater near Winslow, Arizona.

## Comets

Most comets reside in the Oort cloud, some 50 to 100,000 AU in diameter around the Sun. Comet nuclei orbit in this frozen abyss until they are gravitationally perturbed into new orbits that carry them close to the Sun. Many of the nearly 900 recorded comets have orbital periods in excess of 200 years. Some comets pass through the solar system only once, while others have their orbits gravitationally modified by a close encounter with one of the giant outer planets. These latter visitors can enter closed elliptical orbits and repeatedly return to the inner solar system.

The nucleus of a comet is an irregularly shaped, almost black aggregate of water ice, carbon, silicone, methane, and ammonia. The average size of the nucleus ranges from 1 to 10 km in diameter. As a nucleus falls inside the orbits of the outer planets, the volatile elements of which it is made gradually warm. By the time the nucleus enter the region of the inner planets, these volatile elements are boiling, forming a coma, or cloud-like "head" that can measure tens of thousands of kilometers across. The coma grows as the comet gets closer to the Sun.

The charged particles from the Sun, known as the solar wind, push on the coma blowing it back and forming "tails." One tail consists of gases and ions that blow directly back from the nucleus. The other tail contains dust particles that push back more slowly. As the nucleus orbits, the dust particles are left behind in a curved arc. Both the gas and dust tails point away from the Sun; in effect, the comet chases its tails as it recedes from the sun. The tail can reach 150 million km in length, but the total amount of material contained in this dramatic display would fit in an ordinary suitcase.

# Solar System Statistics

| Categories | Sun | Mercury | Venus | Earth | Mars | Jupiter | Saturn | Uranus | Neptune | Pluto |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Mean Distance From Sun (Millions of Kilometers) | — | 57.9 | 108.2 | 149.6 | 227.9 | 778.3 | 1,427 | 2,871 | 4,497 | 5,914 |
| 2. Period of Revolution | — | 88 days | 224.7 days | 365.3 days | 687 days | 11.86 years | 29.46 years | 84 years | 165 years | 248 years |
| 3. Equatorial Diameter (Kilometers) | 1,390,000 | 4,880 | 12,100 | 12,756 | 6,786.8 | 143,200 | 120,000 | 51,800 | 49,528 | ~2,330 |
| 4. Atmosphere (Main Components) | Hydrogen Helium | Virtually None | Carbon Dioxide | Nitrogen Oxygen | Carbon Dioxide | Hydrogen Helium | Hydrogen Helium | Helium Hydrogen Methane | Hydrogen Helium Methane | Methane + ? |
| 5. Moons | — | 0 | 0 | 1 | 2 | 16 | 18 | 15 | 8 | 1 |
| 6. Rings | — | 0 | 0 | 0 | 0 | 3 | 1,000 (?) | 11 | 4 | 0 |
| 7. Inclination of Orbit to Ecliptic | — | 7° | 3.4° | 0° | 1.85° | 1.3° | 2.5° | 0.8° | 1.8° | 17.1° |
| 8. Eccentricity of Orbit | — | .206 | .007 | .017 | .093 | .048 | .056 | .046 | .009 | .248 |
| 9. Rotation Period | 26.8 days | 59 days | 243 days retrograde | 23 hours 56 min. | 24 hours 37 min. | 9 hours 55 min. | 10 hours 40 min. | 17 hours 12 min. retrograde | 16 hours 7 min. | 6 days 9 hours 18 min. retrograde |
| 10. Inclination of Axis* | 7.25° | Near 0° | 177.2° | 23° 27' | 25° 12' | 3° 5' | 26° 44' | 97° 55' | 28° 48' | 120° |

* *Inclinations greater than 90° imply retrograde rotation.*

# Instructions for Puzzle Assembly



### Materials

Solar System Puzzle Patterns*
Cellophane Tape
Colored marker pens or pencils
Scissors
Razor blade craft knife
Butter knife
Cutting surface
Metal edge ruler
White glue (optional)

* If possible, copies of the puzzle patterns should be printed on 60 - 100 pound weight white paper or could be glued on poster board. Otherwise, have the patterns duplicated at a commercial copier business on heavy paper stock.

### Instructions

1. Carefully cut out each cube pattern.
2. Using the razor blade knife and a cutting surface beneath, cut the center of the small slots on each pattern. Matching tabs will be inserted into these slots.
3. With the metal edge ruler for a guide, use the butter knife to score the white dashed lines on each pattern. Be sure not to press down so hard that the paper is cut. The score lines will make it easy to fold the patterns precisely. Also score the tabs and flaps.
4. Pre-fold each pattern piece on the score lines to make sure the folds are square.
5. Each pattern page forms a single cube. Join the corresponding tabs and slots (A to A, B to B, etc.) of the puzzle pieces to begin forming cubes. Use tape on the inside of the cube joint to hold these pieces together firmly.
6. Join the edges of the cubes together by inserting tabs into the corresponding slots cut into the flaps. Work your way around the cube until all sides are joined. You may wish to use the point of the razor blade knife to assist you in getting the last tabs in place. (Assembly gets easier with practice!) After assembling each cube, you can make them stronger by pulling the tabs slightly from their slots and placing a small drop of glue on the tabs. Push the tabs back in and set the cube aside to dry.
7. When all cubes are assembled, put the puzzle together. Starting with one side of the puzzle at a time, begin coloring the images of the objects pictured. Use the coloring instructions as a guide or have students find images of the planets and Sun in astronomy books and try to match the colors in the puzzle. You can also color the captions.

### Alternate Construction Techniques

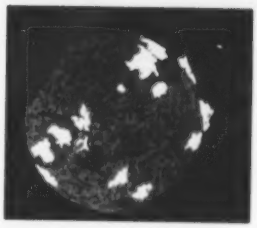
A more rugged puzzle can be constructed by gluing the squares to blocks of wood or other materials. Reduce or expand the patterns on a copy machine to fit the blocks. Be sure to place the squares in the proper positions so that properly oriented puzzle faces will be created.

### Activities and Questions

1. Assemble the puzzle cubes so that all sides match. The exterior faces of the puzzle picture the Sun and five planets. The other objects are visible when the inside faces are opened.
2. Based on the information contained in the chart on page 8, discuss the different sizes of the objects pictured in the puzzle. Because of vast differences in between the Sun and the planets, no consistent scale has been used for the images. Have students draw a circle on the chalkboard one meter in diameter. Then have the students draw other circles to represent the planets to scale. Use the chart on page 8.
3. Discuss the distances between the planets. Make a scale model of the distances of the planets using the distance between Earth and the Sun as a reference. Let that distance equal one meter.
4. Why is it difficult to create a scale model of the solar system with both distance and diameters to the same scale?
5. Why are only the rings of Saturn shown on the puzzle and not the rings of Jupiter, Uranus, and Neptune?
6. Why is only half of Mercury pictured?
7. Have other nations sent spacecraft to study the planets? Which ones?
8. What spacecraft made the picture of Pluto?
9. Why is Pluto shown with its single moon Charon?
10. If you were the first explorer to travel to the other planets, what would you want to learn about them?

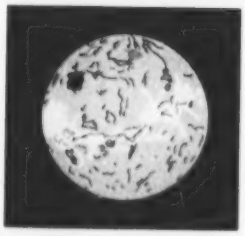
# Color Guide

**Sun:**
Color the entire disk of the Sun yellow. Add orange and red over the mottled areas of the Sun's surface. Leave the white areas yellow. Color the prominences shooting out from the surface red.

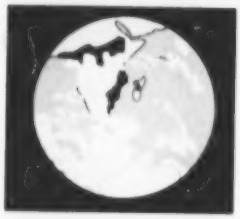


**Mercury:**
Color the entire planet light gray.

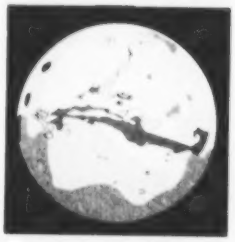
**Venus:**
Color the entire planet orange. Darken the shaded areas with tan or light brown.



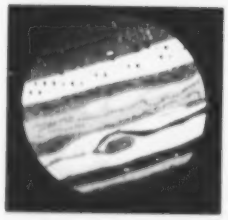
**Earth:**
Color the oceans blue. Leave the clouds and the ice of Antarctica white. Color Africa and Madagascar tan with a green tint. Make the darker shaded areas slightly more brown.



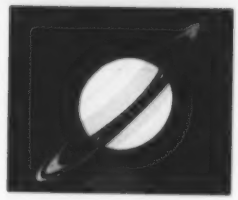
**Mars:**
Color the entire planet orange.



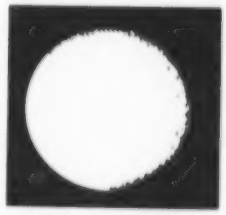
**Jupiter:**
Color the light areas yellow. Make the red spot and the shaded band near it reddish. Color all shaded bands orange with a slight red tint.



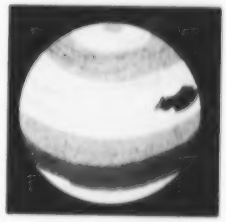
**Saturn:**
Color the entire planet and its rings tan or light orange.



**Uranus:**
Color the entire planet blue green.



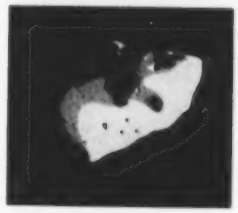
**Neptune:**
With the exception of some white clouds near the Great Dark Spot, color the entire planet light blue. Make the spot and the shaded bands darker blue.



**Pluto and Charon:**
Color the fuzzy outer edges light blue. Leave the centers white.

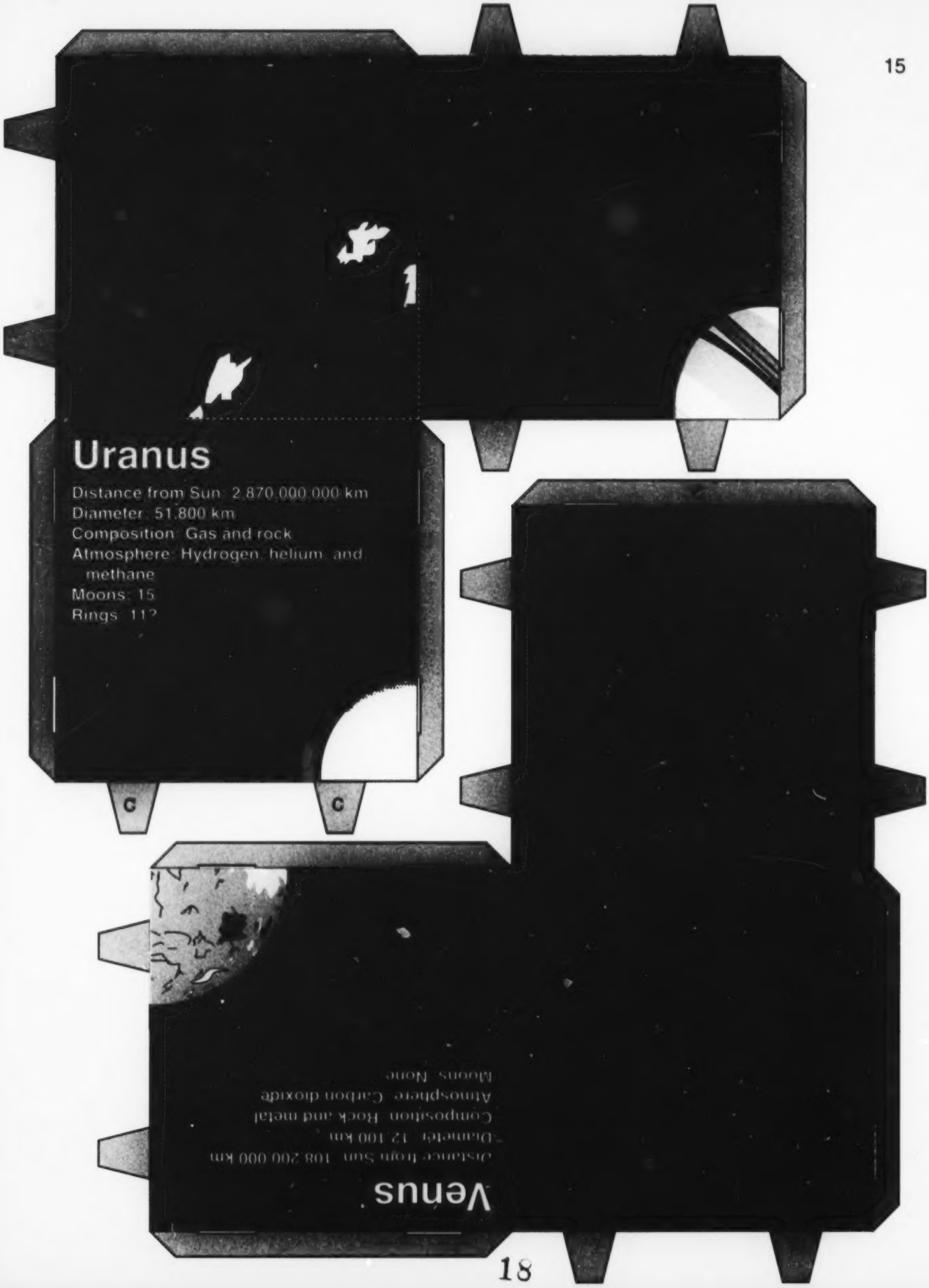
**Comet:**
Leave white.

**Asteroid:**
Color the entire asteroid light gray.



Mars
Distance from Sun: 227,900,000 km
Diameter: 6,786.8 km
Composition: Rock and metal
Atmosphere: Carbon dioxide
Moons: 2
Sun
Diameter: 1,392,000 km
Rotation: 27 days
Composition: Hydrogen and Helium
Surface Temperature:
About 5,800 degrees C
Neptune
Distance from Sun: 4,497,000,000 km
Diameter: 49,528 km
Composition: Gas and rock
Atmosphere: Hydrogen, helium
and methane
Moons: 8
A
A
A
11

Saturn
Distance from Sun: 1 427 000 000 km
Diameter: 120 000 km
Composition: Gas and rock
Atmosphere: Hydrogen and helium
Moons: 18
Rings: 1 000 +
Earth
Distance from Sun: 149 600 000 km
Diameter: 12 756 km
Composition: Rock, metal, water
Atmosphere: Nitrogen and oxygen
Moons: 1
B
B
B


1
Uranus
Distance from Sun: 2,870,000,000 km
Diameter: 51,800 km
Composition: Gas and rock
Atmosphere: Hydrogen, helium, and methane
Moons: 15
Rings: 11?
C
C
Venus
Distance from Sun: 108,200,000 km
Diameter: 12,100 km
Composition: Rock and metal
Atmosphere: Carbon dioxide
Moons: None

D

D

D

## Comets

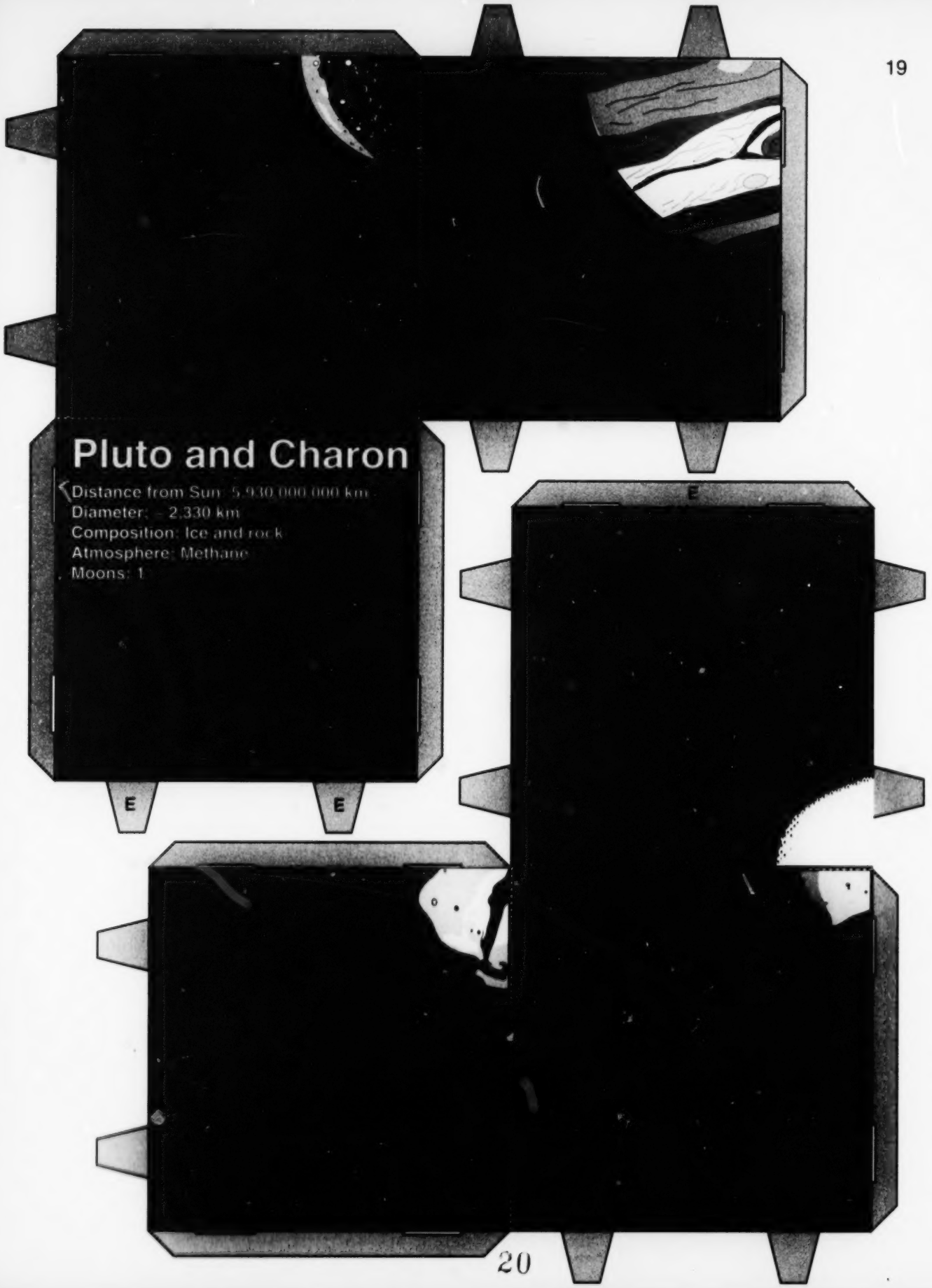
Distance from Sun: Ranging from millions
to trillions of km
Diameter: 1-10 km
Composition: Dust and ice
Atmosphere: Water ice turns to gas when
warmed by Sun

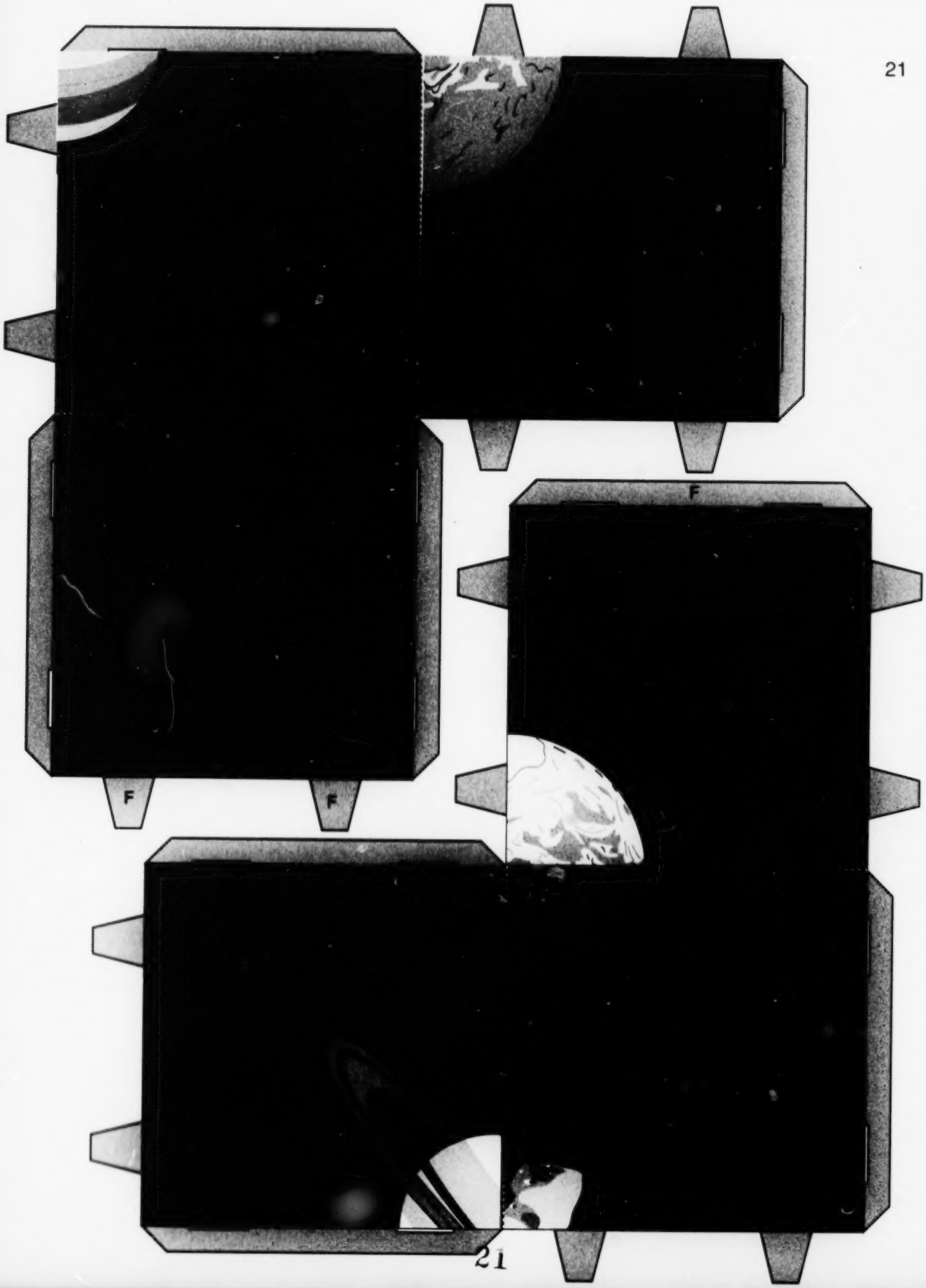
## Mercury

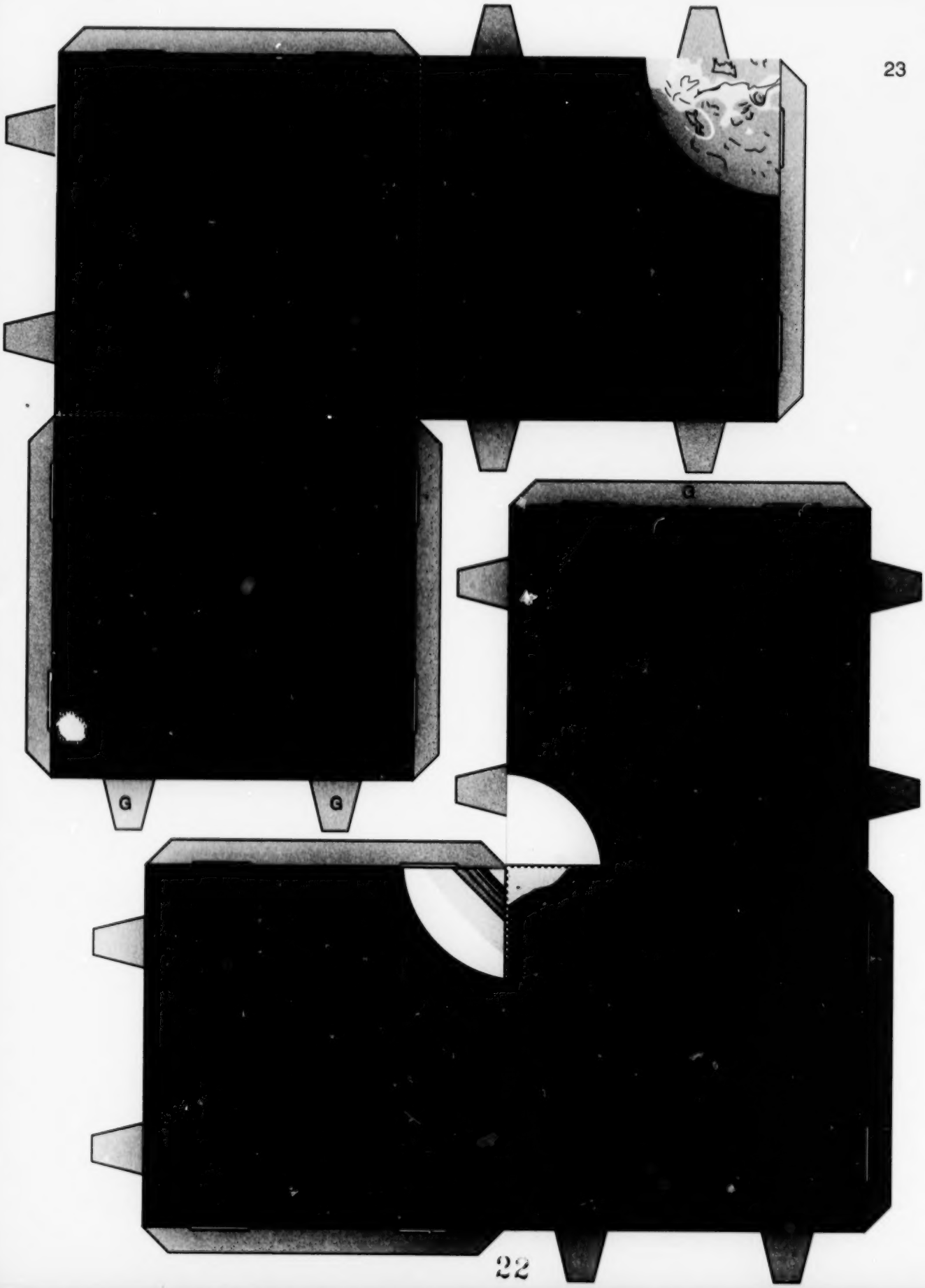
Distance from Sun: 57,9 000 000 km
Diameter: 4 880 km
Composition: Rock and metal
Atmosphere: None

## Jupiter

Distance from Sun: 778 300 000 km
Diameter: 143 200 km
Composition: Gas and rock
Atmosphere: Hydrogen and helium
Moons: 16
Rings: 1


Pluto and Charon
Distance from Sun: 5,930,000,000 km
Diameter: 2,330 km
Composition: Ice and rock
Atmosphere: Methane
Moons: 1
E
E
E


F
F
F


G
G
G

Asteroids (Gaspra)
Distance from Sun: Inner asteroid belt
(~400 million km)
and outer belt (~400 million km)
Diameter: 1–1 000 km
Composition: Rock and metal
Atmosphere: None
H
H

# NASA Resources for Educators



For more information on NASA education programs for the classroom, teachers may contact the following:

**NASA's Central Operation of Resources for Educators (CORE)** was established for the national and international distribution of NASA-produced educational materials in audiovisual format. Educators can obtain a catalogue of these materials and an order form by written request, on school letterhead to:

**NASA CORE**
Lorain County Joint Vocational School
15181 Route 58 South
Oberlin, OH 44074
PHONE: (216) 774-1051, Ext. 293 or 294

## Teacher Resource Center Network

To make additional information available to the education community, the NASA Education Division has created the NASA Teacher Resource Center (TRC) network. TRCs contain a wealth of information for educators: publications, reference books, slide sets, audio cassettes, videotapes, telelecture programs, computer programs, lesson plans, and teacher guides with activities. Contact the TRC in your region (see the listing below) for details on the services they provide:

*AK, AZ, CA, HI, ID, MT, NV, OR, UT, WA, WY*
NASA Teacher Resource Center
Mail Stop T12-A
**NASA Ames Research Center**
Moffett Field, CA 94035-1000
PHONE: (415) 604-3574

*CT, DE, DC, ME, MD, MA, NH, NJ, NY, PA, RI, VT*
NASA Teacher Resource Laboratory
Mail Code 130.3
**NASA Goddard Space Flight Center**
Greenbelt, MD 20771-0001
PHONE: (301) 286-8570

*CO, KS, NE, NM, ND, OK, SD, TX*
NASA Teacher Resource Room
Mail Code AP2
**NASA Johnson Space Center**
2101 NASA Road One
Houston, TX 77058-3696
PHONE: (713) 483-8696

*FL, GA, PR, VI*
NASA Educators Resource Laboratory
Mail Code ERL
**NASA Kennedy Space Center**
Kennedy Space Center, FL 32899-0001
PHONE: (407) 867-4090

*KY, NC, SC, VA, WV*
Virginia Air and Space Museum
NASA Teacher Resource Center for
**NASA Langley Research Center**
600 Settler's Landing Road
Hampton, VA 23669-4033
PHONE: (804) 727-0900 x 757

*IL, IN, MI, MN, OH, WI*
NASA Teacher Resource Center
Mail Stop 8-1
**NASA Lewis Research Center**
21000 Brookpark Road
Cleveland, OH 44135-3191
PHONE: (216) 433-2017

*AL, AR, IA, LA, MO, TN*
U.S. Space and Rocket Center
NASA Teacher Resource Center for
**NASA Marshall Space Flight Center**
P.O. Box 070015
Huntsville, AL 35807-7015
PHONE: (205) 544-5812

*MS*
NASA Teacher Resource Center
Building 1200
**NASA John C. Stennis Space Center**
Stennis Space Center, MS 39529-6000
PHONE: (601) 688-3338

*Serves inquiries related to space and planetary exploration*
NASA Teacher Resource Center
Mail Stop CS-530
**NASA Jet Propulsion Laboratory**
4800 Oak Grove Drive
Pasadena, CA 91109-8099
PHONE: (818) 354-6916

*CA cities near the facility*
Public Affairs Office (Tri 42)
NASA Teacher Resource Center
**NASA Dryden Flight Research Facility**
Edwards, CA 93523-0273
PHONE: (805) 258-3456

*VA and MD's Eastern Shores*
NASA Teacher Resource Lab
Education Complex -Visitor Center
Building J-17
**NASA Wallops Flight Facility**
Wallops Island, VA 23337-5099
PHONE: (804) 824-2297/2298

**Regional Teacher Resource Centers (RTRCs)** offer more educators access to NASA educational materials. NASA has formed partnerships with universities, museums, and other educational institutions to serve as RTRCs in many states. Teachers may preview, copy, or receive NASA materials at these sites. A complete list of RTRCs is available through CORE.

**NASA Spacelink** is an electronic information system designed to provide current educational information to teachers, faculty, and students. Spacelink offers a wide range of computer text files, software, and graphics related to the space program.

The system may be accessed by computer though direct-dial modem or the Internet.

| | |
|---|---|
| Modem line: | (205) 895-0028 |
| Terminal emulation: | VT-100 required |
| Data format: | 8-N-1 |
| Telnet: | spacelink.msfc.nasa.gov |

Spacelink fully supports the following Internet services:

| | |
|---|---|
| World Wide Web: | http://spacelink.msfc.nasa.gov |
| Gopher: | spacelink.msfc.nasa.gov |
| Anonymous FTP: | spacelink.msfc.nasa.gov |
| Internet TCP/IP address: | 192.149.89.61 |

For more information, contact: Spacelink Administrator, Education Programs Office, Mail Code CL01, NASA Marshall Space Flight Center, Huntsville, AL 35812-0001.
Voice phone: (205) 961-1225
E-mail: comments@spacelink.msfc.nasa.gov

## NASA Educational Satellite Videoconferences

The Education Satellite Videoconference Series for Teachers is offered as an in-service education program for educators through the school year. The content of each program varies, but includes aeronautics or space science topics of interest to elementary and secondary teachers. NASA program managers, scientists, astronauts, and education specialists are featured presenters. The videoconference schedule is available on NASA Spacelink.

The videoconference series is free to registered educational institutions. To participate, the institution must have a C-band satellite receiving system, teacher release time, and an optional long distance telephone line for interaction. Arrangements may also be made to receive the satellite signal through the local cable television system. The programs may be videotaped and copied for later use.

For more information, contact: Videoconference Producer, NASA Teaching From Space Program, 308 A CITD, Oklahoma State University, Stillwater, OK 74078-0422
E-mail: nasaedutv@smtpgate.osu.hq.nasa.gov

**How to Access NASA Education Materials and Services, PED-329 April 1995.** This brochure serves as a guide to accessing a variety of NASA materials and services for educators. Copies are available through the TRC network.

# Electronic Resources for Educators

Many of the planetary images in this publication are available to educators in the file "Welcome to the Planets," via the World Wide Web (WWW) located at: http://stardust.jpl.nasa.gov/planets.

Copies of the CD-ROM "Welcome to the Planets" for Macintosh and DOS/Windows platforms are available for purchase through the National Space Science Data Center. Contact:
Request Coordination Office
National Space Science Data Center
Code 633.4
NASA Goddard Space Flight Center
Greenbelt, MD 20771
E-mail: request@nssdca.gsfc.nasa.gov

The following listing of Internet addresses will provide users with robust links to earth and space science educational materials throughout the WWW. NASA resources begins with sites that cover a range of topics and becomes increasingly science specific.

## NASA Resources

NASA SpaceLink (See page 19.)
http://spacelink.msfc.nasa.gov

NASA Home Page
http://www.nasa.gov/

NASA Goddard Space Flight Center Space Science Education Home Page
hhttp://www.gsfc.nasa.gov/education/education_home.html

NASA Mission To Planet Earth Home Page
http://www.usra.edu/mtpe/mtpe.html

NASA Jet Propulsion Laboratory Learning Link
http://learn.jpl.nasa.gov

Remote Sensing Public Access Center
http://www.rspac.ivv.nasa.gov

Public Access to NASA's Planetary Data
http://stardust.jpl.nasa.gov/public

Lunar and Planetary Institute
http://cass.jsc.nasa.gov/lpi.html

Astronomy On-line: Ask Dr. Sue
http://sdcd.gsfc.nasa.gov/ISTO/ASK

NASA/JPL Imaging Radar Home Page
http://southport.jpl.nasa.gov

Global Quest: The Internet in the Classroom
http://quest.arc.nasa.gov

## Other Earth and Space Science Resources

Arizona Mars K-12 Educational Supplement and Guide
http://esther.la.asu.edu/cgi-bin/imagemap/tes_home?144,327

Astronomical Society of the Pacific
http://www.physics.sfsu.edu/asp/asp.html

Earth System Science Education Program
Universities Space Research Association
http://www.usra.edu/esse/Educational_Resources.html

The Nine Planets: A Multimedia Tour of the Solar System
http://seds.lpl.arizona.edu/nineplanets/nineplanets/nineplanets.html

The Planetary Society
http://planetary.org/tps/

San Francisco State University Physics and Astronomy
http://www.physics.sfsu.edu/educate.html

Space Telescope Science Institute (STScI)
http://www.stsci.edu

Space Telescope Science Institute Exploration in Education (EXInED) Picture Books
http://stsci.edu/exined-html/exined-home.html

Telescopes In Education
http://www.mtwilson.edu/tie.html

YAHOO
http://www.yahoo.com/Education

Educators and scientists at the National Aeronautics and Space Administration would appreciate your taking a few minutes to respond to the statements and questions below. Please affix proper postage and return by mail.

SA - Strongly Agree
A - Agree
D - Disagree
SD - Strongly Disagree

## Solar System Puzzle Kit

| | | | | |
|---|---|---|---|---|
| 1. The kit integrated into the curriculum. | SA | A | D | SD |
| 2. The information on the bodies of the solar system enhanced the educational value of the kit. | SA | A | D | SD |
| 3. The instructions provided sufficient information and were understandable. | SA | A | D | SD |
| 4. The kit was useful and appropriate for the grade level I teach. | SA | A | D | SD |
| 5. a. What features of the kit are particularly helpful in your teaching? | | | | |

b. What changes would make the kit more effective for you?

6. I teach_____ grade. Subjects _____

7. I used the guide with_____ (number of) students.

8. Additional comments:



Today's date: _____

EP-328 June 95

Cut along line

PLEASE PLACE
STAMP HERE
POST OFFICE WILL
NOT DELIVER
WITHOUT PROPER
POSTAGE

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**
**EDUCATION DIVISION**
**MAIL CODE FET**
**WASHINGTON, DC 20546-0001**